Beam Stability
Driven by the Science

- Beam Stability Workshop, SRI 2001, SRC
  - Collective input
  - Bob Hettel & Glen Decker
- SRC, input
  - Joe Bisognano
  - Emil Hallin (CSRF user, now CLS)
  - Bob Pedley & John Stott (SHADOW scripts/calcs)
  - Bob Bosch ID compensations

Introduction

- Beam stability = electron + photon
  - Albeit, AP-spin, here
  - Everybody's problem, however
- "We see this. And you don't???"
- Find users using/seeking beam stability that you hadn't even spec'ed. Not articulated. Blindsided.

Why Beam Stability?

- Science-driven: Existing & future experiments need to specify/drive facility's evolution.
- GPRA, ideal
  - Inherently quantifiable
- User's endpoint: "Best machine is a boring machine."

G.P.R.A.

And, most fundamentally, under the Government Performance and Results Act of 1993 (GPRA), every major federal agency must now ask itself some basic questions: **What is our mission? What are our goals and how will we achieve them? How can we measure our performance? How will we use that information to make improvements?** GPRA forces a shift in the focus of federal agencies—away from such traditional concerns as staffing and activity levels and toward **a single overriding issue: results. GPRA requires agencies to set goals, measure performance, and report on their accomplishments.**

Challenges

- Tantalus to Aladdin: 10^{-5} to $<10^{-3}$.
  - Missing class of experiments (modulation spectroscopy)
  - Why?
- Bright, diffraction-limited source
  - Stable within diffraction volume
  - Ideally, stable w/o feedback
  - Beamlines/instrumentation of comparable quality. Need equally strong links in chain.

Reality

- Dynamic perturbations (e.g. ID’s) ... require feed-forward/feedback. (Machine examples)
  - Global/local closed-orbit feedback/feedforward
    - Steerers
    - Fast instabilities
  - Focusing/beamsize control
    - Global: “Tune Tracker” (SRC)
    - Local: 8-quad feedforward (SRC)
    - Global/local coupling: vertical sizes & x-y (roll) rotation (SRC, future?)
  - Longitudinal
    - 4Hrf (bunch lengthening) – feedforward (SRC)
    - Feedback

Now What?

- Long germination periods for new diagnostics/innovations. Limited resources. Imperative to plan carefully, and long in advance.
- Two approaches
  - Serendipity - "If you see you can improve it, then do so." Reactive cures.
  - Methodical – Driving-term management
    - Determine what is required (by users/science)
    - Develop long-term planning for upgrades
      - Budget/manpower resources
      - Decide priorities (most science per allocated resources)
      - Design/schedule improvements (machine, beamlines, instrumentation)
      - Deliverables vs. time

Mandates

- Engage users in active dialog.
  - Convey: they are integral/active part of a dynamic process. Their feedback is important/crucial
  - Speak in their terms. Assume they may see source as only black-box.
  - Generate quantitative measures of critical parameters.
  - Determine requirements for existing/future experiments
- Involve beamline designers, accelerator physics, controls, operations, engineering
  - Need for common dialog and participation.
  - Adopt cooperative, no-fault attitudes
  - Pursue common/shared/interface diagnostics/methods
- Outcome: Consequential, prioritized improvements

Forums

- Generally: Facility user meetings.
- Stability committees?

- Performance Issues Workshop, ALS, Oct 2000.
  - Brought up for discussion.
- Workshop, SRI 2001, UW-Madison, Aug 2001.
  - [www.src.wisc.edu/sri2001/workshop_2/transcript_and_attachments.pdf]
  - Contribution from R. Hettel & pointer to G. Decker
- CLS ID Workshop & Users Meeting
- Performance Issues Workshop, APS, 2002(?)
- Int’l SRI 2003, ALS(?)

Rationale

- Beginning w user requirements, on a particular beamline, operated in a particular mode
- Determine requisite stability of (moving upstream)
  - Instrumentation
  - Optical delivery system
  - Source
- Subsequently determine stability requirements for sub-systems
  - Instrumentation ...
  - Optical delivery system ...
  - Source: pinning-points, fields, ...; examples

Source Subsystems, Examples

- Frequencies
- Power supplies
- HVAC
- Cooling
- Vibrations
- Optical monitoring stations, software
- Feedback systems
- Etc., etc., etc.

Anything Else?

- This is NOT just a source problem!
- Optical monitors into feedback?
- ID monitors – a chronic problem
- Heightened sensitivity from misalignments.
- Can optical systems be designed to be less sensitive?
- Are beamlines sensitive to angles?
  - Typically, ring BPM's assure positional stability and imply angular stability.
- Adaptive optics? More than just steering.

Anything Else? (cont.)

- Internal beamline feedback?
- Beamline/user to ring-controls feedback?
- Absolute vs relative diagnostics.

Preventative/Maintenance

- Diagnostic beamlines
- Data-mining - process logged data for stability information vs varying time intervals. Quantify stability/improvements.
- Beamline characterization – very instructive
  - From ring-side, raster photon beam across BL acceptance; positions/angles, both planes
  - Hypersensitive? Relative misalignment?
  - Regular basis
- Periodically take/process ring steerer-response & beta/coupling data.

User Parameters - examples

- Throughput [%]
- Energy
  - Central value [% of resolution]
  - Spread/resolution [%]
- Image
  - Positions [% of size]
  - Size [%]
  - Quality [?; using acceptance into N-sigma ellipse]
- Other?
  - Polarization
  - Temporal (e.g. IR)
  - ???

Ring-Side Parameters

- Transverse positions/angles, both planes
- Transverse sizes/divergences, both planes
- Longitudinal-axis rotation/coupling (i.e. roll)
- Energy
- Temporal (time, phase)
- Current
- Other?

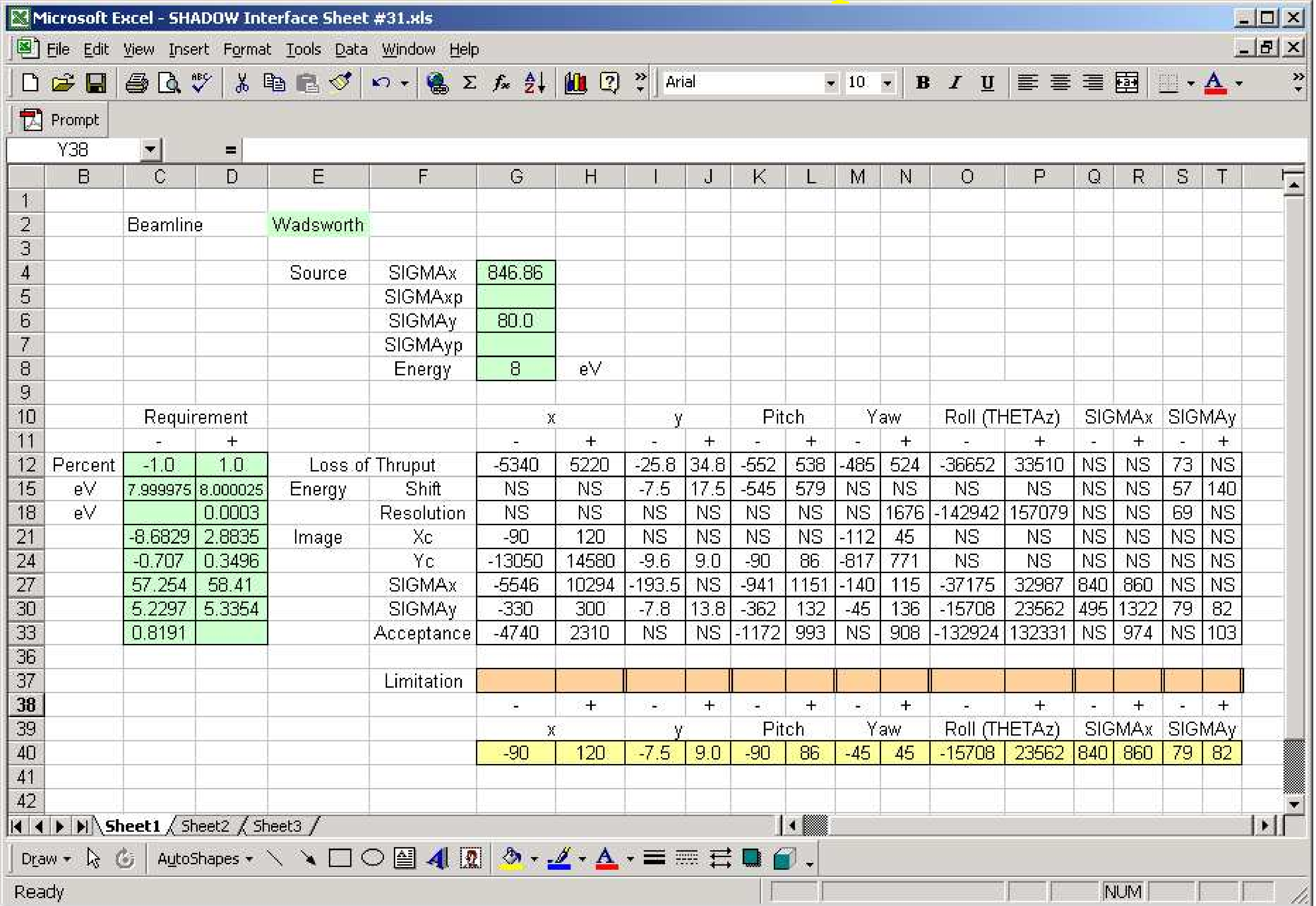
Relationships

- Using optical raytracing software (e.g. SHADOW)
- Functionalities: user and source/ring (or instrumentation/beamline) parameters
- Assumptions
  - Single-source-parameter & photon-energy variations
  - Other (e.g. optical-delivery) systems ideal, aligned
- For given beamline/mode
  - Matrix of relationships
  - Impose user requirements to perform a given experiment (basic step)
  - Everything else falls into place after this!!!
  - Find limiting dependencies for each source parameter
    - from which subsequently deduce allowed magnet, bpm, etc., etc., etc., errors

IR & Other Exceptions

- Don't know how to invert
- Can empirically study relationships by impressing signatured-oscillations onto beam
- Excellent example of Science/Instrumentation benefiting machine performances

Matrix, Example



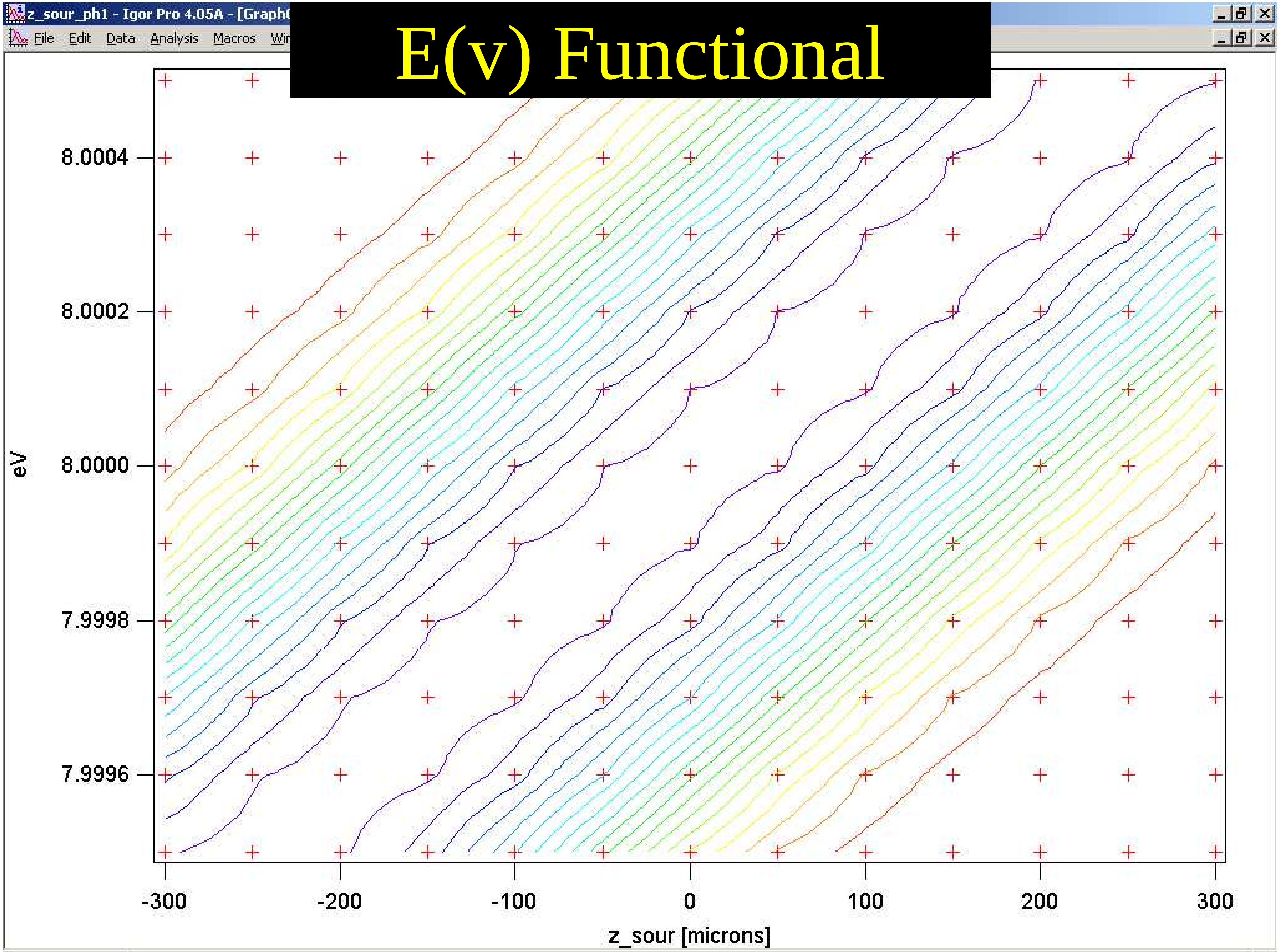
	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																			
2		Beamline		Wadsworth															
3																			
4				Source	SIGMAx	846.86													
5					SIGMAxp														
6					SIGMAy	80.0													
7					SIGMAyp														
8					Energy	8	eV												
9																			
10		Requirement				x		y		Pitch		Yaw		Roll (THETAz)		SIGMAx		SIGMAy	
11		-	+			-	+	-	+	-	+	-	+	-	+	-	+	-	+
12	Percent	-1.0	1.0	Loss of Thruput		-5340	5220	-25.8	34.8	-552	538	-485	524	-36652	33510	NS	NS	73	NS
15	eV	7.999975	8.000025	Energy	Shift	NS	NS	-7.5	17.5	-545	579	NS	NS	NS	NS	NS	NS	57	140
18	eV		0.0003		Resolution	NS	NS	NS	NS	NS	NS	NS	1676	-142942	157079	NS	NS	69	NS
21		-8.6829	2.8835	Image	Xc	-90	120	NS	NS	NS	NS	-112	45	NS	NS	NS	NS	NS	NS
24		-0.707	0.3496		Yc	-13050	14580	-9.6	9.0	-90	86	-817	771	NS	NS	NS	NS	NS	NS
27		57.254	58.41		SIGMAx	-5546	10294	-193.5	NS	-941	1151	-140	115	-37175	32987	840	860	NS	NS
30		5.2297	5.3354		SIGMAy	-330	300	-7.8	13.8	-362	132	-45	136	-15708	23562	495	1322	79	82
33		0.8191			Acceptance	-4740	2310	NS	NS	-1172	993	NS	908	-132924	132331	NS	974	NS	103
36																			
37					Limitation														
38						-	+	-	+	-	+	-	+	-	+	-	+	-	+
39						x		y		Pitch		Yaw		Roll (THETAz)		SIGMAx		SIGMAy	
40						-90	120	-7.5	9.0	-90	86	-45	45	-15708	23562	840	860	79	82
41																			
42																			

Polynomial Fitting Coefficients

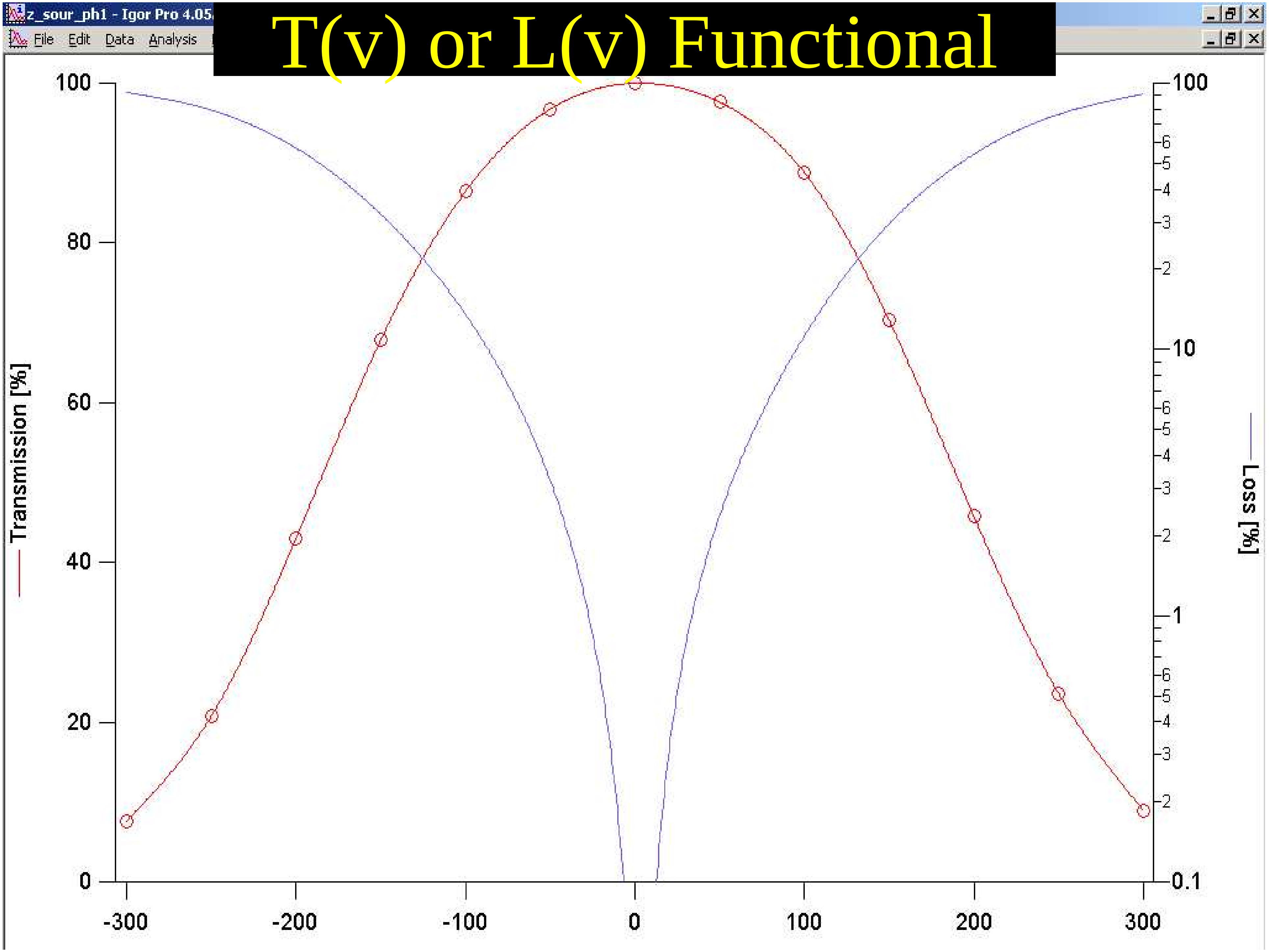
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		Abscissa								Polynomial Fit Coefficients													
2	Function	min	max	Constant	Linear	Quadratic	Cubic	Quartic	etc.														
3	L(x)	-15000	15000	0.0243246	1.07E-05	2.27E-09	-3.93E-13	8.83E-16	1.42E-20	1.42E-24	2.57E-28	4.39E-31	-6.20E-36	-4.92E-39	3.69E-44	1.94E-47	-6.89E-53	-2.68E-56	0	0	0	0	0
4	E(x)	-10000	10000	8	9.78E-11	1.32E-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	dE(x)	-15000	15000	0.0002513	2.31E-11	-1.58E-14	-7.30E-19	1.09E-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Xc(x)	-15000	15000	-2.89968	0.0637451	-1.53E-07	1.70E-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Yc(x)	-15000	15000	-0.178695	-2.98E-07	4.95E-09	4.41E-14	-3.56E-17	-4.46E-22	1.30E-25	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Sx(x)	-9000	13000	57.832	-5.95E-05	8.69E-09	1.71E-13	7.48E-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Sy(x)	-15000	15000	5.28256	0.00017649	6.66E-08	-1.03E-12	-1.82E-16	2.48E-21	2.78E-25	0	0	0	0	0	0	0	0	0	0	0	0	0
10	R(x)	-15000	15000	0.862187	-1.05E-05	-3.89E-09	1.23E-13	1.43E-17	-6.17E-22	-2.27E-26	1.07E-30	1.99E-36	0	0	0	0	0	0	0	0	0	0	0
11	L(y)	-300	300	0.0393275	-0.0087558	0.0010315	-4.90E-07	2.57E-08	4.05E-11	-5.36E-13	-1.10E-15	2.93E-18	1.28E-20	3.70E-25	-5.28E-26	-2.53E-29	0	0	0	0	0	0	0
12	E(y)	-250	250	7.99999	2.01E-06	7.38E-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	dE(y)	-100	100	0.00025122	-4.77E-10	-1.57E-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Xc(y)	-250	300	-0.17042	-0.002201	-5.57E-06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Yc(y)	-300	300	-0.154521	0.0569883	1.52E-06	-4.21E-07	-2.54E-12	1.83E-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Sx(y)	-250	250	57.7354	-0.0010171	5.67E-06	-3.63E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Sy(y)	-300	300	5.23707	0.00037555	-6.91E-05	7.56E-09	7.38E-10	-4.92E-13	-3.22E-15	4.06E-18	0	0	0	0	0	0	0	0	0	0	0	0
18	R(y)	-300	300	0.867396	-7.79E-06	2.92E-06	1.09E-09	-4.82E-11	-1.96E-14	2.74E-16	1.02E-19	0	0	0	0	0	0	0	0	0	0	0	0
19	L(pitch)	-1221.7	1221.7	0.0631731	-8.93E-05	-2.91E-06	4.14E-09	3.60E-11	-1.85E-14	-1.26E-16	3.13E-20	3.15E-22	-2.29E-26	-2.46E-28	6.02E-33	6.13E-35	0	0	0	0	0	0	0
20	E(pitch)	-1221.7	1221.7	7.99999	8.92E-09	1.34E-10	-7.05E-14	-8.67E-17	1.29E-19	5.53E-23	-7.68E-26	-3.34E-29	1.17E-32	1.03E-35	0	0	0	0	0	0	0	0	0
21	dE(pitch	-1221.7	1221.7	0.00025162	4.12E-11	-7.03E-12	-3.91E-16	4.07E-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Xc(pitch	-1221.7	1221.7	-0.220409	-0.0001086	-3.74E-08	3.20E-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Yc(pitch	-1221.7	1221.7	-0.177926	0.00605176	3.44E-06	-5.03E-10	-1.08E-12	-3.48E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Sx(pitcl	-1221.7	1221.7	57.7701	-0.0004004	1.44E-07	-1.62E-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Sy(pitcl	-1221.7	1221.7	5.25821	0.00037898	1.65E-06	-3.22E-10	-1.05E-12	5.58E-17	2.45E-19	0	0	0	0	0	0	0	0	0	0	0	0	0
26	R(pitch)	-1221.7	1047.2	0.861636	-2.42E-05	-7.47E-08	2.66E-11	3.63E-14	1.20E-18	1.49E-20	-7.91E-24	-1.51E-26	0	0	0	0	0	0	0	0	0	0	0
27	L(yaw)	-1745.3	1745.3	0.0252932	0.00011287	1.37E-06	-2.58E-09	-5.01E-12	4.08E-15	6.98E-17	-2.65E-21	-5.25E-23	7.71E-28	1.47E-29	-8.22E-35	-1.48E-36	0	0	0	0	0	0	0
28	E(yaw)	-1047.2	1047.2	7.99999	4.85E-09	5.12E-11	-5.58E-14	-3.68E-17	1.05E-19	9.27E-24	-5.33E-26	3.17E-30	0	0	0	0	0	0	0	0	0	0	0
29	dE(yaw)	-1745.3	1745.3	0.00025104	1.53E-09	-4.70E-13	-2.78E-15	7.10E-20	1.35E-21	2.86E-25	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Xc(yaw)	-1745.3	1745.3	-0.295332	0.0746748	6.66E-06	-7.41E-09	-1.31E-12	6.15E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Yc(yaw)	-1745.3	1745.3	-0.172142	-4.43E-05	1.04E-06	1.92E-10	-3.33E-13	-1.35E-16	-8.44E-21	2.98E-23	1.93E-26	0	0	0	0	0	0	0	0	0	0	0
32	Sx(yaw)	-1745.3	1745.3	57.9023	0.00457348	-5.37E-07	-2.05E-09	-3.27E-13	4.16E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	Sy(yaw)	-1745.3	1745.3	5.25595	0.0005738	1.49E-07	-4.41E-11	-4.86E-14	-1.30E-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	R(yaw)	-1745.3	1745.3	0.861029	-5.52E-05	-5.99E-09	1.40E-11	4.86E-15	-1.27E-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	L(roll)	-261799	261799	-0.0603225	5.61E-06	8.15E-10	-2.20E-15	3.16E-20	2.00E-25	-2.63E-30	-8.83E-36	9.02E-41	2.02E-46	-1.66E-51	-2.29E-57	1.57E-62	1.02E-68	-6.03E-74	0	0	0	0	0
36	E(roll)	-157080	157080	7.99999	5.63E-12	5.98E-17	-3.79E-22	9.88E-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	dE(roll)	-261799	261799	0.00025014	6.09E-11	-2.54E-15	-8.92E-21	2.54E-25	3.03E-31	-6.74E-36	-4.03E-42	8.37E-47	1.90E-53	-3.96E-58	0	0	0	0	0	0	0	0	0
38	Xc(roll)	-261799	261799	-0.213807	-2.84E-06	-4.50E-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Yc(roll)	-261799	261799	-0.156533	2.23E-07	3.53E-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Sx(roll)	-261799	261799	58.0371	-3.53E-06	-6.49E-10	3.98E-16	3.83E-21	-1.05E-26	5.63E-32	7.85E-38	-6.73E-43	0	0	0	0	0	0	0	0	0	0	0
41	Sy(roll)	-261799	261799	5.27838	-1.15E-06	1.58E-10	1.41E-16	-8.88E-21	-6.26E-27	3.25E-31	1.46E-37	-6.92E-42	-1.69E-48	7.66E-53	7.73E-60	-3.37E-64	0	0	0	0	0	0	0
42	R(roll)	-148353	148353	0.861649	9.11E-08	-9.45E-12	-1.18E-17	1.05E-21	3.99E-28	-5.54E-32	-1.59E-39	1.05E-42	0	0	0	0	0	0	0	0	0	0	0
43	L(Sx)	211.71	1481.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	E(Sx)	211.71	1481.9	7.999994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	dE(Sx)	211.71	1481.9	2.51E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	Xc(Sx)	211.71	1481.9	0.137001	-0.000167	-3.02E-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	Yc(Sx)	211.71	1481.9	-0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	Sx(Sx)	211.71	1481.9	16.6645	0.0311352	2.70E-05	-7.81E-09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	Sy(Sx)	211.71	1481.9	5.21865	-1.70E-05	7.97E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	R(Sx)	211.71	1481.9	0.980826	-0.0002487	9.78E-07	-1.85E-09	1.23E-12	-2.84E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	L(Sy)	20	140	0.102835	0.00742552	-0.002111	0.00013	-3.60E-06	4.85E-08	-2.95E-10	6.61E-13	0	0	0	0	0	0	0	0	0	0	0	0
52	E(Sy)	32	140	7.99989	1.37E-06	1.50E-08	-2.86E-10	9.95E-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	dE(Sy)	20	140	0.00029902	3.09E-06	-1.04E-07	9.19E-10	-2.51E-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	Xc(Sy)	20	140	-0.342858	-0.001323	3.05E-05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	Yc(Sy)	20	140	-0.188586	-0.0003431	6.50E-06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	Sx(Sy)	20	136	57.8441	0.00027472	-4.19E-06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	Sy(Sy)	20	140	1.53603	0.00080468	0.0014744	-1.47E-05	4.23E-08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	R(Sy)	20	140	0.947821	-0.0007957	5.10E-05	-1.47E-06	1.27E-08	-3.54E-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59																							

Sheet1 | Sheet2 | Sheet3

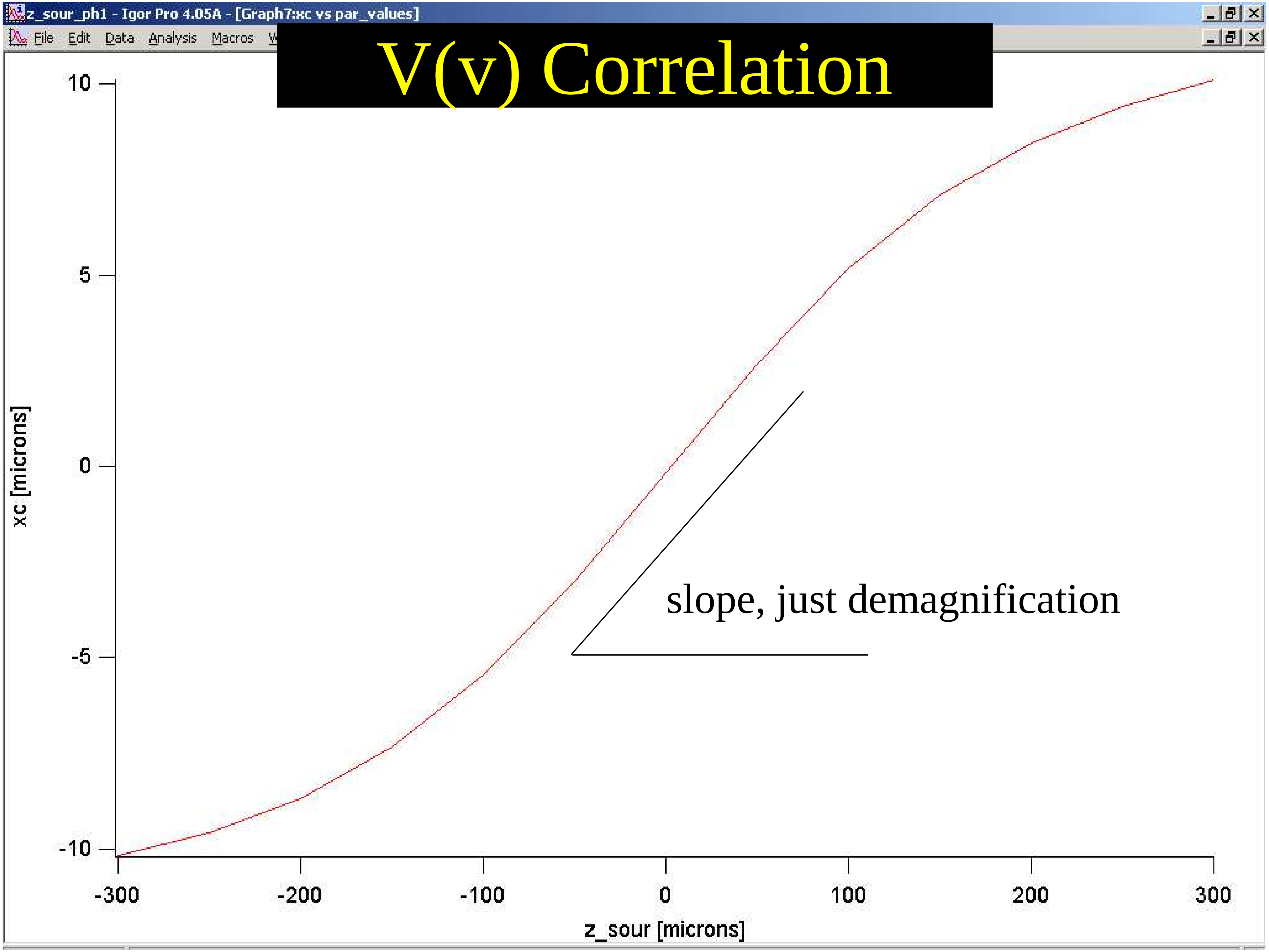
E(v) Functional



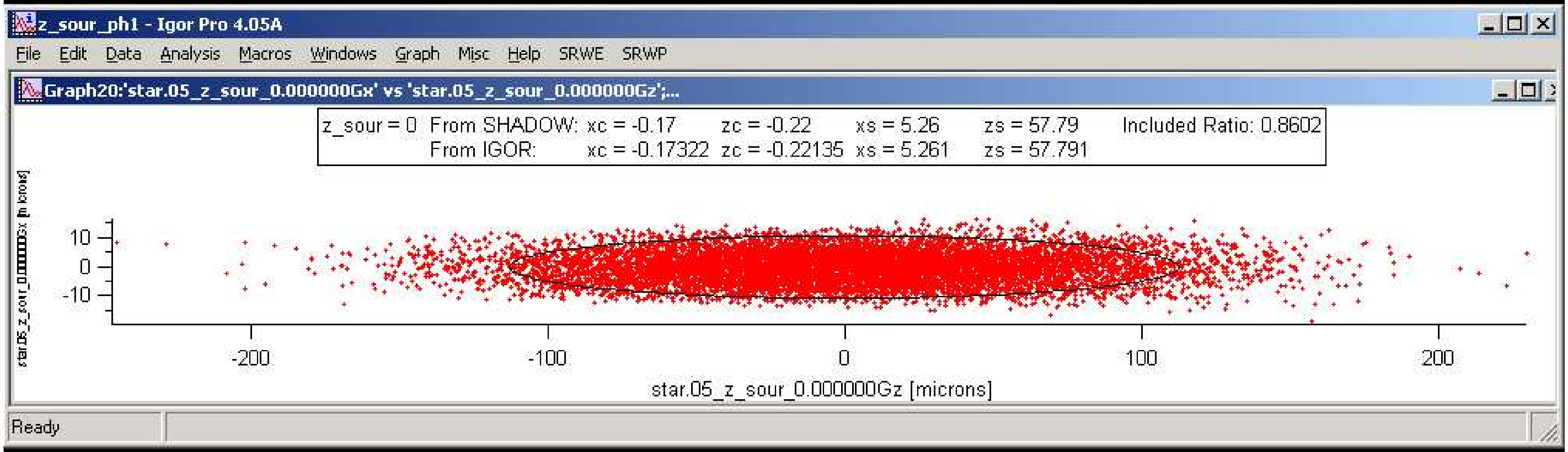
T(v) or L(v) Functional



V(v) Correlation



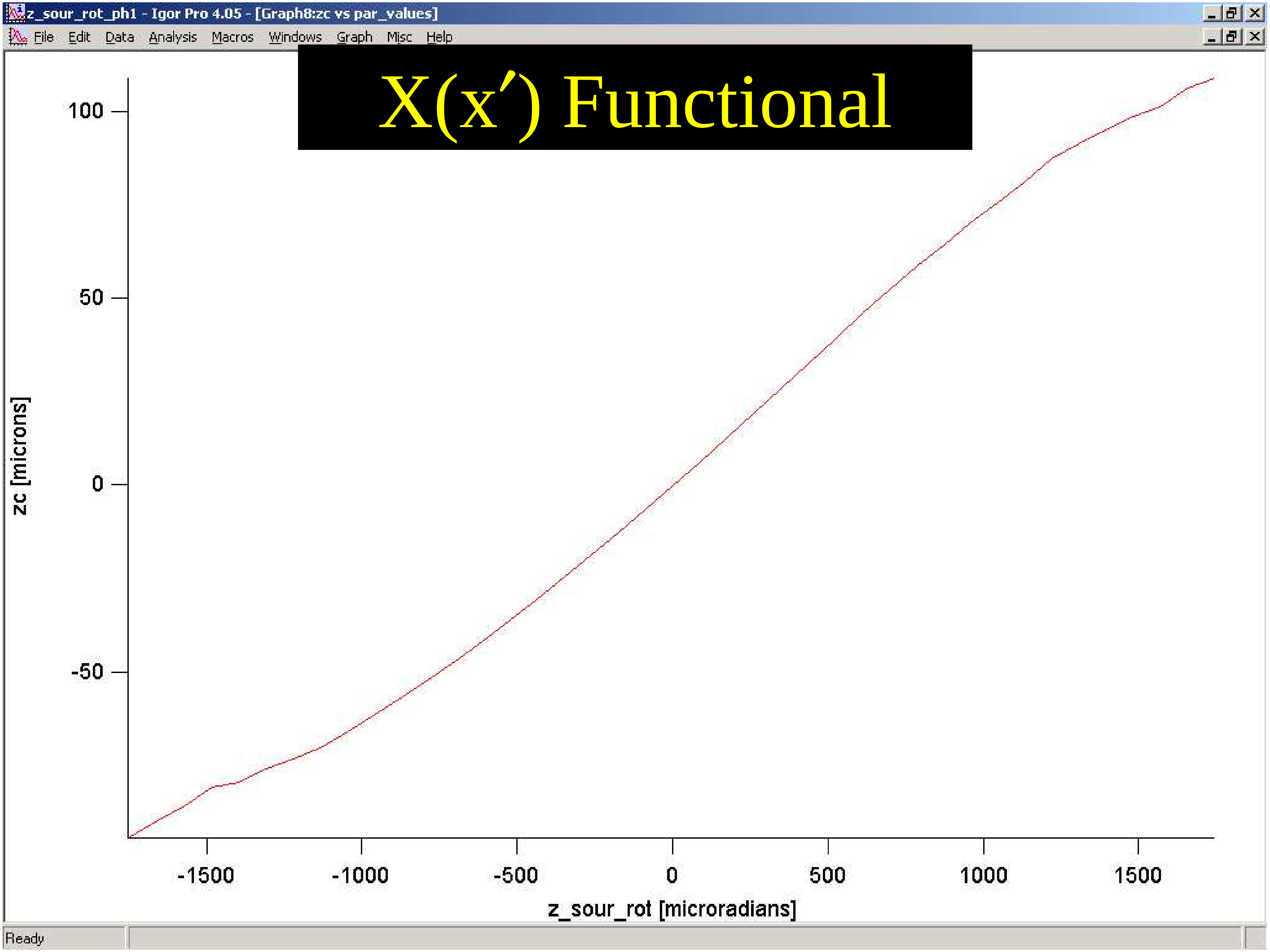
Included Image



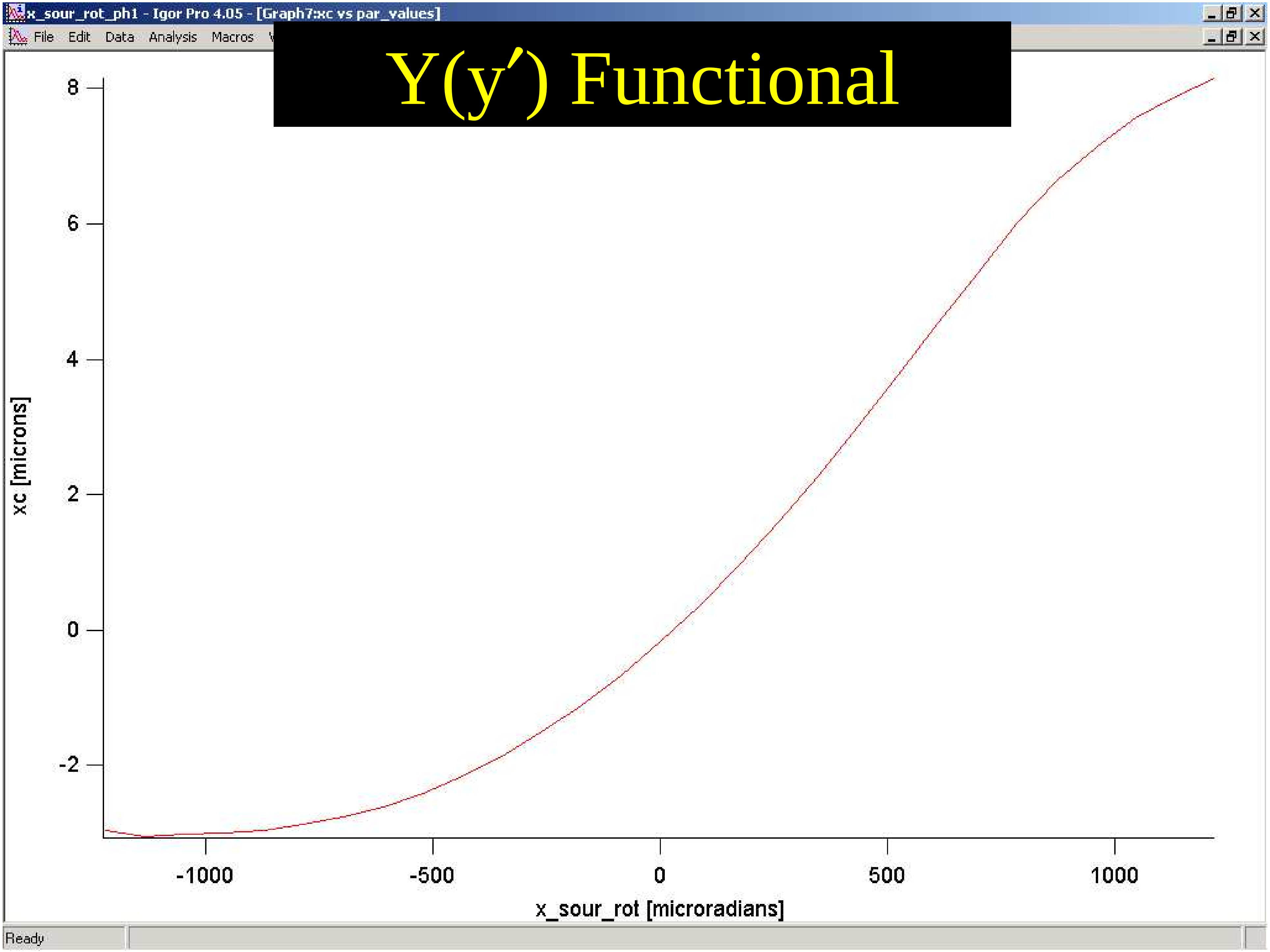
Source Image onto CCD

3.8 deg rotation
minor, vertical 63.5 microns
projected, vertical 71 microns
horizontal, 478 microns

X(x′) Functional



Y(y′) Functional



Questions

- Pass believable test?
- Why see $X(x')$, $Y(y')$ "coupling"?